

**FINAL REPORT OF THE MAJORITY OF THE ACTIVE PARTICIPANTS OF
INFORMAL WORKING GROUP 1 TO
MSSAC ABOVE 1 GHz NEGOTIATED RULEMAKING COMMITTEE**

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SUMMARY

FINAL REPORT OF THE MAJORITY OF THE ACTIVE PARTICIPANTS OF INFORMAL WORKING GROUP 1 TO THE MSSAC ABOVE 1 GHZ NEGOTIATED RULEMAKING COMMITTEE

IWG1 evaluated two distinct approaches to accommodating different Mobile Satellite Service/Radio Determination Satellite Service ("MSS/RDSS") systems in the 1610-1626.5 and 2483.5-2500 MHz bands -- full band interference sharing and band segmentation.

Five applicants and one potential applicant have agreed that they can all viably operate their systems only by full-band spectrum sharing. The sixth applicant, Motorola has steadfastly maintained that its "vision" does not allow it to make any design changes to conform to an interference sharing environment. It has maintained that it can only operate in frequency assigned to it on an exclusive basis and must operate bidirectionally in L-band.

This IWG1 Majority Report concludes that the full band interference sharing proposal is the best sharing proposal because it can accommodate multiple applicants and new applicants, which would offer a wide range of new and low-cost services domestically and internationally, such as voice, paging, facsimile and data. It would also provide safeguards so that spectrum can be reassigned if some licensees do not make use of their assigned share. The inherent flexibility associated with this approach will allow systems to effectively respond to the market environment and, therefore, will best serve the public interest.

In this regard, this Report reaches the following conclusions and recommendations:

- (a) There is sufficient spectrum to accommodate all of the pending applicants with some adjustments to all currently proposed system designs and Celsat.
- (b) A resource allocation plan, whether allocating frequency segments, time slots, or interference power, should be based upon sound principles and avoid arbitrariness. A fundamentally important principle for resource allocation is the equitable treatment of licensees. Since MSS/RDSS is a new service, equity requires that each applicant receive equal access to the spectrum resource.
- (c) The only viable means of assigning the available spectrum resource among multiple systems is Full Band Interference Sharing. Such an approach is the most flexible and spectrum efficient, provides the greatest aggregate capacity, facilitates international coordination, promotes competition, and avoids

inequitable assignment of different portions of the band with greater sharing constraints. This is the only approach that allows the pending applicants to share on a co-frequency, co-coverage basis with each other and with systems operated by other countries and still permits entrance by Celsat. This approach allows multiple systems to share spectrum using a few technical sharing rules without resorting to complicated algorithms based on traffic projections. It also minimizes sharing problems with other services in the bands.

- (d) In principle, both geostationary and non-geostationary satellite systems can operate in the MSS bands on an interference sharing basis provided that system parameters are chosen appropriately. No restriction on the selection of orbit needs to be placed on applicants.
- (e) The Full Band Interference Sharing approach can be extended to accommodate non-spread spectrum systems since FDMA/TDMA systems can be configured to operate in a manner that causes no more equivalent interference than a spread spectrum system, provided that it does not operate bidirectionally.
- (f) The FCC should not authorize the use of the secondary MSS downlink at 1613.8-1626.5 MHz because of potential interference to other U.S. satellite systems. Bi-directional satellite systems cannot share on a co-coverage, co-frequency basis with other satellite systems or with other radio services in the band, and no coordination should be required between secondary and primary services. The analysis has shown that the secondary downlink cannot share on a co-coverage, co-frequency basis with U.S. MSS uplinks using an interference sharing approach since it would cause a reduction in capacity for these systems.
- (g) The FCC should adopt rules that grant all pending applicants satisfying these recommendations authorizations to construct, launch and operate their proposed systems, subject to coordination among the immediate and future operators and the use of default values for certain critical parameters such as downlink PFD and uplink areal EIRP density.
- (h) The FCC should adopt rules that specify the Default Values described in Section 2.1 of the IWG1 Majority Report and provide as follows: "In order to insure compliance with the agreed upon, or default (as the case may be), values discussed above, all MSS licensees will cooperate with each other in good faith to resolve questions concerning alleged violations of the coordination agreement reached between them. Each

licensee shall (1) make available to any other coordinating licensee raising such question, subject to an appropriate confidentiality agreement, all pertinent technical data in the possession of such alleged offending licensee necessary to resolve such question, and (2) promptly undertake to alter its system operations as required to correct such violations as may have occurred."

- (i) In recognition of the substantial net increase in U.S. MSS capacity to be realized through the addition of yet another CDMA applicant such as Celsat and the incremental public benefit which would flow therefrom, and subject to the limitations and rights of current applicants under the cutoff rules, the IWG1 Majority Report recommends that the Celsat system receive the fair consideration to which it is entitled as a new entrant when and if it chooses to formalize the work which it has done with respect to bandsharing in an FCC application.

The rules implementing these recommendations are specified in Section 9 of this Report.

1. Background

This report describes and evaluates proposed methods of achieving multiple entry and sharing among satellite systems in the 1610-1626.5 MHz and 2483.5-2500 ("MSS/RDSS Bands").

At the 1992 World Administrative Radio Conference ("WARC-92"), spectrum was allocated internationally for MSS in these bands. The bands 1610-1626.5 MHz (earth-to-space) and 2483.5-2500 MHz (space-to-earth) were allocated on a primary basis. The band 1613.8-1626.5 MHz was also allocated on a secondary basis for MSS downlinks. The Federal Communications Commission ("FCC") has proposed (in ET Docket No. 92-28) domestic allocations for MSS/RDSS in the bands consistent with allocation decisions made at WARC-92. IWG1 Majority Report, § 1.

Applications to provide mobile satellite service (MSS) and radiodetermination satellite service (RDSS) in these bands have been filed by six corporations: Constellation Communications, Inc. ("Constellation"), Ellipsat Corporation ("Ellipsat"), Loral Qualcomm Satellite Services ("LQSS"), Motorola Satellite Communications, Inc. ("Motorola"), TRW Inc. ("TRW"), and American Mobile Satellite Corporation ("AMSC"). Celsat, Inc. ("Celsat") has indicated an intention to file an application to use the MSS/RDSS bands.

In general, the applicants have proposed to provide a variety of services including near-toll quality voice, data, paging,

facsimile, and RDSS (position determination) to users with handheld and/or vehicular terminals. Five applicants have proposed to offer such services through a network of low or medium earth orbiting (LEO) satellites. The sixth applicant ("AMSC") proposes to provide services within the United States using geostationary satellites. Celsat also proposes to use geostationary satellites in conjunction with terrestrial facilities. Most importantly, five applicants and Celsat propose to utilize CDMA or spread TDM access format to share the 1610-1626.5 MHz and 2483.5-2500 MHz bands. Motorola proposes to use a TDMA/FDMA access format in the 1616-1626.5 MHz band on a bidirectional basis and claims that it cannot share spectrum with the other proposed systems. The nominal parameters of these systems are described in Section 1 of this Report.

2. Description of Sharing Approaches

In order to accommodate the proposed systems in these bands, two approaches have been identified: Full Band Interference Sharing and Band Segmentation.

a. **Full Band Interference Sharing.** The basic elements of the full band interference sharing approach recommended by six proposed system operators to accommodate multiple satellite systems in the 1610-1626.5 MHz and 2483.5-2500 MHz bands include the following:

- Each applicant is granted a license to operate across the entire 1610-1626.5 MHz and 2483.5-2500 MHz bands, or portions of these bands as requested.
- These licenses are conditioned on a successful completion of coordination by the licensees with each other (i.e., those who filed applications within the current cut-off period).
- Existing MSS licensees would have an obligation to coordinate with new licensees as authorized by the Commission, and in the absence of agreement, default values would apply.
- Default values for the maximum downlink PFD spectral density and maximum aggregate uplink EIRP areal spectral density would be imposed by the FCC on each satellite system licensee if agreement on different values is not reached during the coordination process among licensees.
- This technical coordination in the MSS/RDSS bands is based on the equitable allocation of interference noise among multiple systems sharing the bands.
- At the completion of coordination, the licensees would certify to the Commission that coordination has been successfully completed. If necessary, the licensees

would also file any applications for modifications of authorized parameters needed to implement the coordination agreement.

As a general technical matter, this approach can be applied to both spread spectrum and non-spread spectrum systems, as well as to LEO and GEO systems. However, practical sharing results may not be obtained for specific spread and non-spread systems with widely different characteristics. For example, the design of the proposed Motorola system precludes spectrum sharing on a co-frequency, co-coverage basis with the proposed CDMA systems under this approach.

b. Band Segmentation. A band segmentation approach to sharing the MSS frequencies requires that: (1) each system is authorized to operate in some segment of the 1610-1626.5 MHz band, which might not be an exclusive spectrum assignment; and (2) criteria are established for assigning spectrum segments to each authorized system. Motorola has proposed a plan for segmenting the 16.5 MHz band of uplink spectrum into two 8.25 MHz wide sub-band segments based on access technology. (Motorola takes no position as to how the S-band downlink should be shared.) The basic elements of this plan for domestic implementation are as follows:

- All qualified applicants would receive a permit to construct systems that can operate over both bands in their entirety (i.e., up to 33 MHz), or as much thereof as they have requested in their applications.
- The first operational system would be permitted to use both bands in their entirety in the U.S., or as much thereof as it has been authorized to use. A system would be considered "operational" when it commences providing commercial MSS services as authorized by the Commission.
- If two systems become operational and employ different types of modulation techniques, the TDMA/FDMA system would operate in the upper half of the band (1618.25-1626.5 MHz) and the CDMA system would operate in the lower half of the band (1610-1618.25 MHz).
- If three or more systems become operational and at least one employs a different type of modulation technique than the others, TDMA/FDMA systems would share the 1618.25-1626.5 MHz portion of the band through an exclusive assignment of frequency and the CDMA systems would share the 1610-1618.25 MHz portion of the band through interference sharing.

Other band segmentation approaches identified in Section 2 of this Report include: (1) Band Segmentation by Number of Applicants; (2) Band Segmentation by Channelization; (3) Band

Segmentation by Dynamic Band Sharing; and (4) Hybrid Full Band Polarization Segmentation. Each of these approaches, like the Motorola proposal, would require that procedures be established for assignment of spectrum and dynamic reallocation.

3. Description of Technical Sharing Criteria

During coordination under the full band interference sharing method, system operators would agree on changes to the parameters of their systems to reduce the amount of interference caused to other systems to the agreed upon levels. However, such agreements would only be necessary with respect to a limited number of parameters as identified below, and each system operator would be able to optimize its system in terms of capacity, cost and service quality within these overall sharing constraints. The following are the parameters on which agreement is to be reached during the coordination process:

- Maximum Downlink PFD Spectral Density
- Maximum Aggregate EIRP Areal Spectral Density
- Polarization
- Frequency Plans
- Code Structures and Associated Cross-Correlation Properties
- Antenna Beam Patterns
- Signal Burst Structures
- Overall Interference Allowance

These parameters are described in detail in Section 3 of this Report.

Additionally, the out-of-band emission rule currently found in Section 25.202(f) needs to be updated to reflect the operation of MSS systems. It is proposed that Section 25.202 be amended to specify a power spectral density (PSD) mask measured relative to the average in-band PSD at the maximum design power setting for the MSS/RDSS bands. Proposed out-of-band emission limits are contained in Table 3-1 of this Report. In the event that the out-of-band PSD specified in Table 3.1 of this Report is not met, a waiver to the mask may be allowed if there is a showing that the operation of the equipment would not cause harmful interference to other systems or services or if it is shown that the out-of-band PSD is below a coordinated interference level.

Additionally, a 45 dB isolation is proposed for protection between a TDMA/FDMA system and a CDMA system or systems that are operating at or near capacity.

Table 3-2 of this Report contains the proposed downlink out-of-band emissions limits. The table forms a power spectral density (PSD) mask which protects FDMA/TDMA or CDMA receiving mobile units from emissions from satellite downlinks in another band within the 2483.5-2500 MHz band or within the 1613.8-1626.5 MHz secondary downlink band.

4. Secondary Downlink

The Commission has proposed an allocation in the 1613.8-1626.5 MHz band for MSS downlinks (space-to-earth) on a secondary basis, consistent with the WARC-92 allocations, but has expressed concerns whether bidirectional use of the 1610-1626.5 MHz band is feasible. Notice of Proposed Rule Making, ¶¶ 28-29 (ET Dkt. 82-28). Secondary MSS downlink transmissions present an environment for in-band harmful interference to primary MSS uplinks whenever a system uses secondary downlinks co-coverage, co-frequency with another MSS system operating in the earth-to-space direction anywhere in the world; similarly, the potential for out-of-band harmful interference would occur whenever one system uses the proposed secondary downlinks in a specified segment of the 1610-1626.5 MHz band co-coverage with another MSS system operating in the primary earth-to-space direction in a different specified segment of the band anywhere in the world. IWG1 Majority Report, § 4.1.

Secondary operations are prohibited from causing harmful interference to primary services and cannot claim protection from harmful interference from primary services. "Harmful interference" is defined as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with these Radio Regulations." Radio Regulations, Art. 1, § 7.4 (¶ 163); see IWG1 Majority Report, § 4.2.

Four line-of-sight interference cases were analyzed in which an interfering satellite could cause harmful interference to a victim satellite: (1) backlobe interference into the mainlobe of victim satellite in a higher orbit than the interfering satellite; (2) sidelobe interference into the sidelobe of a victim satellite at a comparable orbital altitude as the interfering satellite; (3) mainlobe interference into a victim satellite from an interfering satellite where the potential interference path is just over the horizon; and (4) backlobe interference into the mainlobe of a victim satellite in a lower orbit than the interfering satellite. IWG1 Majority Report, § 4.3.

For determining emissions of the interfering satellite in this analysis, the parameters of the proposed Iridium system were used. See IWG1 Majority Report, Annex 4.1. Satellites of the proposed systems described in Section 1 were used as the victim satellites. Case 4 above was excluded because the orbit of an Iridium satellite is lower than the orbit of all other currently proposed MSS systems. The effect of interference from secondary downlink operations into the victim satellites was designed to measure loss in capacity while maintaining the call quality of the existing traffic without the interference. IWG1 Majority Report, § 4.4.

In this analysis, backlobe interference displaced from 6 (Ellipsat) to 623 (Constellation) MSS channels per spread bandwidth. See IWG1 Majority Report, § 4.4, Table III. Sidelobe interference reduced from 0 (LQSS) to 31 (TRW) MSS channels per spread bandwidth. In the transhorizon case, the number of signals interfered with ranged from a low of 78 (LQSS) to a high of 7,348 (TRW) per spread bandwidth. The aggregate interference impact on the various proposed systems would be substantial, e.g., 5,241 aggregate voice circuits lost under the sidelobe analysis for Constellation; Celsat would lose an aggregate 41,040 voice circuits in the transhorizon case. IWG1 Majority Report, § 4.4. With respect to time and duration of interference, it was noted that the transhorizon case is always present. The sidelobe and backlobe cases are potentially present in all beams continuously. IWG1 Majority Report, § 4.4, Table V. During these periods, there is a potential loss of capacity up to the maximum specified in the Report.

According to this analysis, the use of secondary downlinks by the Iridium system with the parameters described in Section 4 of this Report would result in harmful interference to each of the proposed systems analyzed for substantial periods of time.

Motorola asserts that certain mitigating effects can be employed to avoid "harmful interference" from secondary downlinks into primary uplinks that may occur and identified five: band segmentation, downlink masking by primary uplink, beam management, frequency management and antenna adjustments. See IWG1 Majority Report, § 4.5. However, this Report concludes that Motorola's suggested mitigating effects would not be sufficient to eliminate harmful interference from Iridium secondary downlinks. These parties recommend that no burden be imposed upon users of primary uplinks in order to avoid harmful interference from secondary downlinks. See IWG1 Majority Report, § 4.6.

Based upon the predicted harmful interference from secondary downlinks, and the apparent infeasibility of Motorola's proposed mitigating effects, this Report concludes that a secondary MSS downlink of the type proposed for Motorola's Iridium system would result in the loss of system capacity for MSS systems operating co-frequency uplinks in an interference sharing environment.

5. Realizable Capacities/Performance Analysis

Realizable capacities and performance of the proposed MSS systems were analyzed based upon a model designed to determine capacities and performance under actual operating conditions. Under the Full Band Interference Sharing approach described in Sections 2 and 3 of this Report, the downlink and uplink for the proposed systems using CDMA access technology were analyzed separately. IWG1 Majority Report, § 5.1.

Results for individual and aggregate CONUS capacities demonstrate that the full-band interference sharing approach

yields substantial capacity while allowing multiple entry for the five or six systems analyzed on an economically viable basis. INGL Majority Report, § 5.1, Tables 1-8. For example, in one of the worst cases analyzed, if the five pending applicants were licensed and using the S-band downlink operating co-polar at a PFD spectral density of $-139.0 \text{ dBW/m}^2/4\text{kHz}$, the total CONUS capacity would be 9199 channels (Table 2); for these five systems using the L-band uplink operating co-polar at an EIRP of $-140.0 \text{ dBW/m}^2/4\text{kHz}$, the total CONUS capacity would be 8579 channels (Table 6). Capacity calculations would increase if Celsat were included as an operating system.

Section 5.1 of the Report describes predicted uplink and downlink capacities for various combinations of operating MSS systems at various PFD spectral density levels and EIRP areal spectral density levels and cross-polarization isolations. Under the various scenarios described, capacities of multiple CDMA systems could range up to 12,000 channels (uplink limited) depending upon the specific systems assumed to be operating.

Using its band segmentation approach (8.25 MHz for each access technology), Motorola calculates that its Iridium system would achieve 3854 CONUS channels if it were the only system operating in the TDMA/FDMA segment. If there were more than one system sharing 8.25 MHz, then overall system capacity would remain approximately the same, and each system would have approximately $1/t$ available channels (where t = number of TDMA systems). INGL Majority Report, § 5.5. The capacity figures used in Section 5B of the Report for the Iridium system were provided by Motorola. In Annex 5.5, a separate analysis concludes that the realizable capacity for Iridium is actually only about 1950 channels over CONUS.

Capacities of CDMA systems operating in the 8.25 MHz allotted for CDMA operation could be calculated by scaling down the analysis in Section 5.1 of this Report for half the bandwidth. Under this band segmentation approach, the maximum available channels for all systems would be approximately 9,570. INGL Majority Report, § 8.2.1. Operating over 8.25 MHz would prove economically infeasible for certain proposed CDMA systems, and so, this figure may not be realistic.

Under the band segmentation approach described as "1/n," capacity may be calculated by scaling back Iridium's capacity for that available in 2.75 MHz, and the CDMA systems' capacity to 13.75 MHz, which equals about 10,000 channels. INGL Majority Report, § 8.2.1. However, not all these channels would be necessarily available because Iridium could achieve only about 1200 channels, which appears not to be sufficient to fulfill Motorola's business plan. According to the separate analysis in Annex 5.5, the Iridium realizable capacity over CONUS in 2.75 MHz is about 650 channels.

A compromise approach to accommodate both CDMA and TDMA systems was also considered. This hybrid full band/polarization segmentation sharing approach would allow all proposed CDMA and TDMA systems to be accommodated in the proposed MSS allocation. See ING1 Majority Report, § 5.2. Under this approach, all proposed systems would be accommodated through use of left- and right-hand circular polarizations (LHCP and RHCP). TDMA/FDMA operation would be permitted in the top 2.75 MHz on both L-band and S-band (i.e., from 1623.75-1626.5 MHz and 2497.25-2500 MHz) with RHCP. CDMA operation would be permitted with LHCP and RHCP in the remaining band segments in their entirety. All operational systems would be required to maintain 6-8 dB of cross-polarization isolation with their mobile terminal antennas and 20 dB cross-polarization isolation with their satellite antennas to minimize interference into systems in the opposite polarization. Band sharing among the CDMA systems would be determined by the interference sharing rules outlined in Sections 2 and 3.

Under this plan, approximately 3640 channels would be available for TDMA/FDMA operation, and 10,000-15,000 voice circuits for multiple CDMA systems. ING1 Majority Report, at § 5.2.3. All systems would be required to modify certain design parameters in order to effectuate this approach. Motorola would have to operate in both L- and S-bands, rather than its proposed bidirectional system, and reduce the TDMA data rate and required power for the TDMA carrier. The CDMA systems would have to accept more interference from TDMA systems operating at a higher PFD level, and some would have to change their channelization schemes to accommodate non-homogenous systems. All systems would have to improve mobile terminal antenna performance and to optimize antenna design. ING1 Majority Report, § 5.2.4. All systems would also have to operate a higher PFD level than the existing coordination trigger of $-142 \text{ dBW/m}^2/4 \text{ kHz}$. ING1 Majority Report, § 5.2.5.

Motorola disagrees on various technical bases with the feasibility of this proposed plan to accommodate all systems. ING1 Majority Report, § 5.2.7. It has also refused to modify the design of its Iridium system in any of the proposed ways to facilitate spectrum sharing and multiple entry. ING1 Majority Report, Annex 5.2.3.

As noted previously, five of the proposed MSS systems would operate in low or medium earth orbit, and two proposed systems would use geostationary satellites. See ING1 Majority Report, § 1.1. All systems propose service to low-powered mobile satellite terminals that have antennas with little or no angular discrimination in either the azimuth or elevation angles of transmission.

Direction is not a factor with these types of mobile terminals when calculating potential interference, and therefore, satellite orbital altitude does not substantially change the intersystem interference environment. ING1 Majority Report,

§ 5.4.1. Accordingly, GEO and LEO systems can share the MSS allocation as long as all systems operate within the agreed upon EIRP spectral density thresholds for the L-band and the PFD limits for the S-band. IWGI Majority Report, § 5.4.2-3. Under the recommended interference sharing approach, LEO and GEO systems should have full access to the bands for CDMA operation.

6. System Descriptions for Sharing Analysis

AMSC, Celsat, Constellation, Ellipsat, LQSS and TRW have all agreed to facilitate full-band interference sharing with other proposed systems in the MSS/RDSS band by modifying system design parameters. A number of proposed design parameters were included in the sharing analysis of Section 5 of this Report. Most systems have proposed an increase in the number of beams per satellite, and several may modify their channelization plans. See IWGI Majority Report, § 6.1.

The capacity of MSS systems in a sharing environment is directly related to the size and number of antenna beams on their satellites. Because each frequency channel can be reused in each beam, there is a nearly proportional increase in capacity from doubling the number of beams that cover the ground. IWGI Majority Report, § 6.2.1.1. The number of beams in a given area has a direct correlation to the realizable capacity of a system. Yet, satellites with more beams are relatively more expensive. In this regard, it should be noted that some of the proposed CDMA systems provide significantly higher number of CONUS channels with 20 or fewer beams for which Iridium requires 59 beams.

Polarization isolation can also be used to maximize shared system capacity. IWGI Majority Report, § 6.2.1.2. Further improvements in the capacities demonstrated in Section 5 of the Report can be obtained depending upon the configuration of the actual systems and coordination parameters. IWGI Majority Report, § 6.2.1.3-4. Anticipated improvements in vocoder and modulation technology would also enhance shared system capacity. IWGI Majority Report, § 6.2.2. In short, the capacity figures represented in Section 5 under the full-band interference sharing analysis should be viewed as conservative for both current and future system designs.

7. Effects of Sharing with Services other than MSS/RDSS

There are several sharing considerations on the use of the bands. First, the lower part of the uplink band (1610.6-1613.8 MHz) is allocated internationally to the Radio Astronomy Service (RAS) on a co-primary basis. MSS and RDSS providers must coordinate use of this part of the spectrum with RAS. Second, Aeronautical Radionavigation Service (ARNS), for example the Russian GLONASS system, shares primary status in one of the bands internationally. GLONASS has been coordinated in accordance with Footnote 732 and Article 14 in the band 1602-1616 MHz. GLONASS currently operates an earth-to-space link in the band 1602-1616

MHz, and has advance published with the IFRB for the GLONASS-M system up to 1620.6 MHz. See IWG1 Majority Report, § 7.2. If sharing with GLONASS cannot be resolved, the 1610-1616 MHz band may be unavailable for MSS/RDSS.

Third, the Global Positioning Service ("GPS") system operates under the radionavigation-satellite (space-to-earth) allocation in the 1559-1610 MHz band and may present out-of-band emission issues. Out-of-band emissions limits would resolve any interference issue related to GPS. See IWG1 Majority Report, § 7.3.

Fourth, the Instructional Television Fixed Service ("ITFS") and the Multichannel Multipoint Distribution Service ("MMDS") operate above 2500 MHz, and certain out-of-band emissions may have an impact on downlink operations in the MSS/RDSS Band. Industrial, scientific and medical applications could also impact operations in the 2483.5-2500 MHz band. These services should not significantly restrict use of the S-band by MSS. IWG1 Majority Report, § 7.4.

8. Analysis of the Sharing Options

In evaluating sharing options and technical rules for the proposed MSS allocation, consideration must be given to Section 1 of the Communications Act of 1934, the FCC's existing policies on domestic and international satellite services, and the ITU Convention. IWG1 Majority Report, § 8.0.

In establishing policies and rules governing domestic satellite services, the FCC has identified four specific objectives: (1) expedite the introduction of new technology and services; (2) afford reasonable opportunity for multiple entry; (3) facilitate removal of institutional restraints on system development; and (4) allow for incorporation of future technological advances. See Domestic Communications-Satellite Facilities, 84 FCC 2d 584, 586 (1980).

The FCC has recognized that multiple entry and competition among satellite system operators fosters these policy objectives by promoting market-driven services, cost-based charges, and technological innovation to improve service. See, e.g., Radio-Determination Satellite Service, 60 RR 2d 298, 301 (1986). This multiple entry policy has a direct bearing on the adoption of technical rules because the FCC should select "the system design which best assures that the benefits of a competitive marketplace are made available to . . . users." Id.; see also Competitive Carrier, 85 FCC 2d 1 (1980).

Moreover, the need for international coordination of satellite systems has long been recognized as a part of U.S. radio communications policy, and the United States, as a member of the ITU, is committed to fostering the shared interests of all Administrations in planning use of spectrum resources. These

interests include: (1) equitable access to the radio frequencies allocated for specific services for all Administrations; (2) efficient and economical resource utilization; (3) use of advanced technology; (4) uniform technical criteria for satellite systems; and (5) adaptability to the features of various Administration requirements and the needs of technological development and new services. See ITU Convention, Art. 33; Space WARC, 100 FCC 2d 976, 1000 (1985).

While each approach should have as its objective the satisfaction of all of the foregoing criteria, the following are critical factors for evaluating the various approaches:

- (a) Maximization of multiple entry;
- (b) Potential aggregate capacity; and
- (c) Facilitating new entrants and international and domestic coordination.

In evaluating the approaches considered, the majority of IWG1 concludes that the Full Band Interference Sharing approach will best serve the public interest because it maximizes multiple entry, promotes competition, and facilitates and domestic and international coordination. Most importantly, the Full Band Interference Sharing approach provides for efficient use of spectrum. It yields increased channel capacity because multiple systems can share the entire band; and unlike Motorola's proposed band segmentation split between TDMA and CDMA systems, the Full Band Interference Sharing approach does not require spectrum to be used for guard bands. Through a relatively few parameters, multiple MSS systems can coordinate and provide more than 10,000 channels over CONUS. No band segmentation approach provides as many channels.

Band segmentation approaches considered generally produce fewer available CONUS channels, and provide only uncertain opportunities for system growth and addition of new entrants beyond the current six applicants. Band segmentation would also likely result in fewer economically viable systems because, where there is more than one system in either the TDMA/FDMA segment or the CDMA segment, there would be relatively few channels available to each. Moreover, there are several disadvantages to band segmentation in general: (1) increased complexity (and cost) of satellite systems wedged into smaller bandwidths; (2) lower overall capacity from increased interference as systems are made more complex to make up for less usable spectrum; (3) loss of capacity gain from multiple CDMA systems using entire bandwidth; (4) spectrum warehousing in one segment because multiple systems cannot reuse the entire bandwidth; and (5) reduced competition. In light of the availability of Full Band Interference Sharing, The various band segmentation approaches do not serve the public interest.

IWG1 also considered the facility of international coordination under the full band interference sharing and band

segmentation approaches. The simplicity of coordination under the full band interference sharing approach would carry over to the international forum. See IWG1 Majority Report, § 8.3. On the other hand, it would be inherently difficult to coordinate a bidirectional system which cannot share spectrum with other MSS systems on a co-frequency, co-coverage basis for the same reasons which make Motorola's Iridium system difficult to coordinate with the other proposed U.S. MSS systems, and authorization of such a system could result in service gaps at the U.S. borders to accommodate foreign or international MSS systems.

1. BACKGROUND.

This report will describe and evaluate proposed methods of achieving multiple entry and sharing among satellite systems in the 1610-1626.5 MHz and 2483.5-2500 MHz MSS/RDSS bands on the basis of Full-Band Interference Sharing and Band Segmentation.¹ Applications to provide mobile satellite service (MSS) and radiodetermination satellite service (RDSS) have been filed by six corporations: Constellation Communications, Inc. (Constellation), Ellipsat Corporation (Ellipsat), Loral Qualcomm Satellite Services (LQSS), Motorola Satellite Communications, Inc. (Motorola), TRW Inc. (TRW), and American Mobile Satellite Corporation (AMSC) (MSS only). Celsat, Inc. (Celsat) has indicated an intention to file an application to use the MSS/RDSS bands.

At the 1992 World Administrative Radio Conference (WARC-92), spectrum was allocated internationally for MSS in these bands on a primary basis. The band 1613.8-1626.5 MHz was also allocated on a secondary basis for MSS downlinks. Subsequently, the Federal Communications Commission (FCC) proposed to allocate the 1610-1626.5 and 2483.5-2500 MHz bands to MSS/RDSS (in ET Docket 92-28) and convened this Negotiated Rulemaking Proceeding (CC Docket 92-166). The charter of the Negotiated Rulemaking Committee (the "Committee") states that "[t]he purpose of the committee is to provide recommendations to the Federal Communications Commission to be used in the formulation of technical rules governing the provision of mobile satellite services (MSS) operating in the 1610-1626.5 MHz (Earth-to-space), 1613.8-1626.5 MHz (space-to-Earth), and 2483.5-2500 MHz (space-to-Earth) frequency bands. The committee will also assist the FCC in resolving questions relating to (1) the maximum sharing of available frequencies for mobile satellite services, and (2) coordination of these services with existing and future terrestrial and/or satellite services, domestically and internationally." (MSSAC-1.)

The Committee created three Working Groups. The Committee's Work Program directs Working Group 1 to "[r]ecommend modifications to the existing rules for these bands (47 C.F.R. § 25.141), or new rules as necessary, to maximize multiple entry and to avoid or resolve mutual exclusivity among the non-geostationary satellite applicants, and between proposed non-geostationary and proposed or authorized geostationary satellite systems, while maintaining the economic viability of the systems." (MSSAC-1.)

The FCC has stated that "[a]pplicants filing by the cut-off date [June 3, 1991] will be afforded an opportunity to amend their

¹ This report was developed in accordance with the work plans previously adopted by the participants.

applications, if necessary, to conform with any requirements and policies that may be adopted for satellite systems in these bands." (Report No. DS-1068 (April 1, 1981).)

In general, the applicants have described a variety of services, which include near-toll quality voice, data, paging, facsimile, and RDSS (position determination) to users with handheld and/or vehicular terminals domestically and, in some cases, internationally. Five applicants have proposed to offer such services through a network of low or medium earth orbiting (LEO) satellites. The sixth applicant (AMSC) proposes to provide services within the United States in the same bands using geostationary (GEO) satellites. Celsat also proposes to use geostationary satellites in conjunction with terrestrial facilities. The fact that several other administrations have submitted advance publication information to the International Frequency Registration Board ("IFRB") for use of these bands indicates that some non-U.S. entities may be interested in constructing MSS systems.

1.1. Nominal Parameters of Proposed LEO and GEO Systems.

This section contains a brief description of the proposed MSS/RDSS systems and some of the nominal parameters of each system.² See also section 1.4, where a tabulation is given for the frequency plan, modulation and channelization scheme of each system.

1.1.1. Constellation. Constellation proposes a LEO satellite system that it calls "Aries", which would provide voice, data, facsimile and RDSS. The proposed system consists of 48 satellites in 4 planes in polar orbits at an altitude of 1020 km above the Earth. As originally filed, Constellation proposed to use SCPC/FDMA uplink transmissions from user terminals and TDM transmissions spread over the 16.5 MHz downlink to user terminals. The system is now under review to increase satellite capacity and will use CDMA access techniques across the 16.5 MHz allocated for user terminal uplink transmissions.

² The information in Section 1 of this Report was provided by each applicant and represents a combination of data from the applications, other FCC filings, current thinking on system design and considerations to maximize the shared use of the MSS/RDSS bands by authorized entities. See Sections 5 and 6 of this Report for additional explanation.

1.1.2. Ellipsat. Ellipsat proposes a satellite system, known as "Ellipso", to provide voice, data, facsimile and RDSS. Ellipsat initially plans to build, launch, and operate 6 LEO satellites, and eventually to increase capacity by expanding to a maximum of 24 satellites. It proposes to operate the satellites in inclined elliptical and equatorial circular orbits with a maximum altitude of 7800 km. Ellipsat claims that its use of elliptical orbits would optimize coverage of the United States with a minimum number of satellites. It plans to operate this system using channelized CDMA digital spread spectrum techniques.

1.1.3. LOSS. Loral Qualcomm Satellite Services proposes a LEO system called "Globalstar" that would provide voice, data, facsimile, and RDSS services. The Globalstar system would use a network of 48 satellites in inclined orbits 1414 km above the Earth. It plans to use a channelized CDMA access technique, based closely on the CDMA wideband digital cellular telephony standard currently being finalized by the Telecommunications Industry Association (TIA).

1.1.4. Motorola. The system proposed by Motorola is known as "Iridium", with which it has proposed to offer voice, data, facsimile and RDSS. Motorola has proposed bi-directional operation in the 1616-1626.5 MHz band. The Iridium system would be composed of 66 LEO satellites in 6 polar orbit planes at an altitude of 780 km above the Earth. Each satellite would be capable of demodulating user signals, and cross-linking them to adjacent satellites. The system would use a TDMA/FDMA access format.

1.1.5. TRW. TRW has proposed a system known as "Odyssey" to provide voice, data, facsimile, and RDSS services. The Odyssey system would employ 12 satellites, four in each of three orbital planes, in a medium-earth orbit at an altitude of 10,370 km. The Odyssey system would employ dynamically steerable satellite antennas and channelized CDMA access techniques.

1.1.6. AMSC. AMSC, the U.S. domestic MSS licensee in the 1545-1559 MHz and 1646.5-1660.5 MHz bands, has requested that the FCC also license it for operation in the 1616.5-1626.5 MHz band and a complementary downlink band on its second and third geostationary satellites to be located at 62° and 139° West Longitude. AMSC states that it needs access to additional spectrum because of limitations imposed on access to its licensed bands due to international coordination. AMSC proposes to use CDMA or narrowband FDMA access techniques.

1.1.7. Celsat. Celsat has not filed an application with the FCC. In its filings in ET Docket 92-28 and RM-7827, however, Celsat has described its "Celstar" concept as comprising a hybrid terrestrial/satellite system which would utilize two redundant

geostationary satellites. It has proposed a channelized CDMA access format, closely based on a CDMA wideband digital cellular telephony standard currently being finalized by the TIA.

Company/System	# of Satellites	Orbit Altitude (km)	Satellite Beams
Constellation/Aries	48	1020	7
Ellipsat/Ellipso	6, later 24	580 x 7800	8
LQSS/Globalstar	48	1414	6
Motorola/Iridium	66	780	48
TRW/Odyssey	12	10,370	19
AMSC	2	Geostationary 62°W/139°W	4
Celsat/Celstar	2	Geostationary 76°W/116°W	149

Table 1: Summary of System Constellation Parameters

1.2. Resources Available.

The FCC has proposed (in ET Docket 92-28) to allocate domestically two 16.5 MHz bands for MSS/RDSS on a primary basis: an uplink band from 1610 to 1626.5 MHz and a downlink band from 2483.5 to 2500 MHz. This allocation for MSS would be co-primary with the existing allocation for RDSS in these bands. The FCC has also proposed a secondary MSS downlink band 1613.8-1626.5 MHz. These band proposals are consistent with allocation decisions made at WARC-92.

1.3. Known Band Sharing Considerations.

There are several sharing considerations on the use of these bands. First, the lower part of the uplink band (1610.6-1613.8 MHz) is allocated internationally to Radio Astronomy Service (RAS) on a co-primary basis. MSS and RDSS providers must coordinate use of this part of the spectrum with RAS.

Second, Aeronautical Radionavigation Service (ARNS) for example, the Russian GLONASS system, share primary status in one of the bands internationally. GLONASS has been coordinated in accordance with Footnote 732 and Article 14 in the band 1602-1616 MHz. GLONASS currently operates a space to earth link in the band 1602-1616 MHz, and has advance published with the IFRB for the GLONASS-M system up to 1620.6 MHz.

A number of footnotes to the ITU's Table of Allocations affect the use of the bands. International Regulation 731E states:

The use of the band 1610-1626.5 MHz by the mobile-satellite service (Earth-to-space) and by the radiodetermination-satellite service (Earth-to-space) is subject to the application of the coordination and notification procedures set forth in Resolution 46 (WARC-92). A mobile earth station operating in either of the services in this band shall not produce an e.i.r.p. density in excess of -15 db(W/4 kHz) in the part of the band used by systems operating in accordance with the provision of No. 732, unless otherwise agreed by the affected administrations. In the part of the band where such systems are not operating, a value of -3 db(W/4 kHz) is applicable. Stations of the mobile-satellite service shall not cause harmful interference to, or claim protection from, stations in the aeronautical radionavigation service, stations operating in accordance with the provisions of No. 732 and stations in the fixed service operating in accordance with the provisions of No. 730.

In addition to Footnote 731E, the FCC has proposed the adoption of several other international footnotes which were approved or modified at WARC-92. These footnotes are set forth below:

731F - The use of the band 1613.8-1626.5 MHz by the mobile-satellite service (space-to-Earth) is subject to the application of the coordination and notification procedures set forth in Resolution 46.

733E -- Harmful interference shall not be caused to stations of the radio astronomy service using the band 1610.6-1613.8 MHz by stations of the radiodetermination-satellite and mobile-satellite services (No. 2904 applies).

734 -- In making assignments to stations of other services, administrations are urged to take all practicable steps to protect the radio astronomy service in the band 1610.6-1613.8 MHz from harmful interference. Emissions from space or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. 343 and 344 and Article 36).

753F -- The use of the band 2483.5-2500 MHz by the mobile-satellite and the radiodetermination-satellite services is subject to the application of the coordination and notification procedures set forth in Resolution 46. Coordination of space stations of the mobile-satellite and radiodetermination-satellite services with respect to terrestrial services is required only if the power flux-density produced at the Earth's surface exceeds the limits in No. 2566. In respect of assignments operating in this band, the provisions of Section II, paragraph 2.2 of Resolution 46 shall also be applied to geostationary transmitting space stations with respect to terrestrial stations.

International Footnotes 727 and 730 provide additional L-band allocations to fixed service on a secondary and primary basis, respectively, in certain foreign countries.

As set forth in Section 7 of this Report, IWG1 received inputs from IWG2 relating to the use of the 1610-1626.5 MHz band by other services.

Third, the downlink band (2483.5-2500 MHz) is also allocated domestically and internationally to various terrestrial services and applications on a primary basis. In the U.S., fixed service systems operate in the band pursuant to U.S. footnote NG 147. To avoid interference to the terrestrial services, WARC-92 set in Footnote 753F a coordination trigger level of $-142 \text{ dBW/m}^2/4\text{kHz}$ on downlink PFD from each satellite (and a lower PFD level at low elevation angles, see ITU RR 2566).

Fourth, WARC-92 allocated the 1613.8-1626.5 MHz band (space-to-earth) on a secondary basis only, whereas the MSS uplinks in the 1610-1626.5 MHz band are allocated on a primary basis.

1.4. Proposed Modulation and Channelization Schemes.

The following table depicts the proposed systems' frequency plans, modulation and channelization schemes as currently envisioned:

Company/System	Modulation	Multiple Access Method (Forward Link)	Multiple Access Method (Return Link)	Channelization (MHz)	Frequency Band (MHz)
Constellation	QPSK	Spread TDM	Channelized CDMA	16.5 forward 1 to 5 return	1610-1626.5 2483.5-2500
Ellipsat	OQPSK	Channelized CDMA	Channelized CDMA	1.1	1610-1626.5 2483.5-2500
LQSS	QPSK	Channelized CDMA	Channelized CDMA	1.25	1610-1626.5 2483.5-2500
Motorola	DE-QPSK	FDMA/TDMA	FDMA/TDMA	41.67 KHz	1616-1626.5
TRW	BPSK	Channelized CDMA	Channelized CDMA	5.5	1610-1626.5 2483.5-2500
AMSC	QPSK	CDMA (or FDMA/TDMA)	CDMA (or FDMA/TDMA)	5.5 MHz (or 6 KHz)	1616.5-1626.5 2483.5-2500*
Celsat	QPSK	Channelized CDMA	Channelized CDMA	1.25	1610-1626.5 2483.5-2500

Table 2: Summary of MSS System Parameters

- * AMSC has indicated an intention to amend its applications to use the 2483.5-2500 MHz band for downlink operations.

2. DESCRIPTION OF SHARING APPROACHES.

2.1. Full Band Interference Sharing.

The basic elements of a full band interference sharing approach proposed by five of the MSS/RDSS applicants and the one stated potential applicant (Celsat) to accommodate multiple satellite systems in the 1610-1626.5 MHz and 2483.5-2500 MHz bands include the following:

- Each applicant is granted a license to operate across the entire 1610-1626.5 MHz and 2483.5-2500 MHz bands, or portions of these bands if so requested.
- These licenses are conditioned on a successful completion of coordination by the licensees with each other (i.e. those who filed applications within the current cut-off period).
- Existing MSS licensees would have an obligation to coordinate with new licensees as authorized by the Commission, and in the absence of agreement, the Default Values shall apply.
- Default Values for the maximum downlink PFD spectral density and maximum aggregate uplink EIRP areal spectral density would be imposed by the FCC on each satellite system licensee if agreement on different values is not reached during the coordination process among licensees.
- This technical coordination in the MSS and RDSS bands is based on the equitable allocation of interference noise among multiple systems sharing the bands.
- At the completion of coordination, the licensees would certify to the Commission that coordination has been successfully completed. If necessary, the licensees would also file any applications for modifications of authorized parameters needed to implement the coordination agreement.

As discussed in Section 3 below, a successful coordination under this full band spectrum sharing proposal requires agreement on only a few basic technical parameters, these principally being a maximum system PFD spectral density in the 2483.5-2500 MHz downlink band and a maximum aggregate mobile terminal EIRP areal spectral density in the 1610-1626.5 MHz uplink band. Coordination of such levels would be done on a group basis, rather than in one-on-one or sequential meetings. In the course of the coordination, all of the parties would mutually agree on the allocation of

interference noise among the systems and exchange any information and interference calculations needed to verify that the agreed upon interference allocations are being achieved.

It is proposed that a technical approach based on an equitable allocation of interference noise would be used in the application of the international coordination procedures set forth in Resolution 46 of the Final Acts of WARC-92, subject to the agreement of other administrations.

The technical basis for this approach is that the effects of interference from other satellite systems sharing the band can be assessed in terms of the contributions to the link $C/(N_0 + I_{Io})$ of each system, which determines the link margin above the required E_b/N_0 , and thus system capacity. This consideration applies independently to the forward (outbound) and return (inbound) paths. Interference in the feeder link bands can also affect the ultimate $C/(N_0 + I_{Io})$ for the link. However, for the simple frequency changing transponders considered by the current CDMA applicants, in many cases it can be assumed that the effects of intersystem interference in the feeder link accounts for a small but fixed amount of additional degradation to the link E_b/N_0 . This allocated degradation to link performance could then be addressed in the separate coordination of feeder link bands if the systems share the same feeder link bands.

In other words, in order to meet the Commission's objectives of flexible multiple entry, this coordination approach requires each system to be designed with sufficient margin to tolerate the interference level received from the other systems that are licensed to operate within the same band. During the coordination process, individual system operators accept that changes in system parameters may be necessary to achieve an equitable distribution of the I_o contribution from their systems to other systems. However, by focussing the coordination agreement on only a few basic or aggregate parameters, system operators retain a large degree of flexibility to optimize their own system design objectives.

Default values for the maximum downlink PFD spectral density and maximum aggregate uplink EIRP areal spectral density are proposed as part of this approach in order to remove possible concerns that the licensees will not achieve mutual agreement on the values of these parameters during the coordination process. Based on the information available during the negotiated rulemaking proceeding, this Report is able to identify values for these parameters on a preliminary basis as defaults while recognizing that the optimum values for these parameters will be the result of the coordination process among the satellite system licensees. The proposed default values for these parameters are specified in Annex 2.1.